DOCUMENT RESUME

ED 236 010 SE 043 289

AUTHOR Schollum, Brendan
TITLE Chemical Change. Learning in Science Project. Working Paper No. 27.
INSTITUTION Waikato Univ., Hamilton (New Zealand).
PUB DATE May 81
NOTE 25p.; For related documents, see ED 226 976, ED 229 442, ED 230 594, ED 235 011-030, SE 043 285-302, and SE 043 305-315. Document contains some marginal legibility.
AVAILABLE FROM University of Waikato, Science Education Research Unit, Hamilton, New Zealand.
PUB TYPE Reports - Evaluative/Feasibility (142) -- Reports - Research/Technical (143)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Change; *Chemical Reactions; Cognitive Processes; Comprehension; *Concept Formation; *Curriculum Development; Elementary School Science; Elementary Secondary Education; Interviews; Learning; Science Education; *Science Instruction; *Secondary School Science
IDENTIFIERS *Learning in Science Project; *New Zealand; Science Education Research

ABSTRACT

One area explored in the second (in-depth) phase of the Learning in Science Project was "children's science," defined as views of the world and the meanings for words that children have and bring with them to science lessons. The investigation reported focuses on students' (N=37) views of chemical change. Data were obtained using the "interview-about-events" method in which students were asked to describe and then explain what happened during each of five events. Student responses are presented, discussed, and analyzed for each event according to categories of the most prevalent views. Events utilized include: (1) placing a vitamin C tablet in water (generating bubbles); (2) lighting gas from a butane burner; (3) heating sugar crystals; (4) showing shiny and rusty nails; and (5) mixing plastic filler/hardener. Prevalent views for the first event (selected as an example) include: bubbles result from chemical reaction; bubbles are caused by physical change in the tablet; or, no knowledge of how bubbles formed. The views discussed under these headings (as well as those discussed for the other four events) indicate that although students have strong ideas about what they saw, their explanations for events, in particular the meaning of "chemical reaction," are quite different from the scientific viewpoint. (JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED236010

LEARNING IN SCIENCE PROJECT

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

CHEMICAL CHANGE

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Roger Osborne

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

University of Waikato
Hamilton, N.Z.

SE043289

WORKING PAPER No. 27

CHEMICAL CHANGE

A Working Paper of the Learning in Science Project

Brendan Schollum
May 1981

This investigation describes the views held by 35 pupils and two Primary Teachers' College students about five everyday events which involve what scientists would call chemical change [1]. A series of structured interviews was used, designed to elucidate views about each particular event. The interviews were held away from science classrooms and the interviewee was helped to relax by some initial general conversation about his/her schooling and interests. Those interviewed[2] were:

1 Form 1 pupil - code number 102
7 Form 2 pupils - code numbers 201-206, 208
8 Form 3 pupils - code numbers 301-307, 309
8 Form 4 pupils - code numbers 401-407, 409
5 Form 5 pupils - code numbers 501-504, 506
6 Form 6 pupils - code numbers 601-605, 607
2 Primary T.C. students - code numbers T1, T2

The pupils interviewed were of a range of abilities. In our view the sample tended to be biased towards more able rather than less able children.

The technique used was the Interview-about-Events described by Osborne (1980). This technique involves an event or activity occurring in front of the person being interviewed. Where possible the person is asked to participate in the event, if only to light a burner. Each event was used as a focal point which enabled the interviewee's view to

---

1 The New Zealand Draft Syllabus for Form 1-4 (1980) in Science has a section on chemical change and normally pupils would study a unit on chemical change in Form 3 or 4. In the Intermediate school the two related units are States of Matter and Pure Substances and Mixtures, in which are highlighed the nature of physical change with certain substances.

2 Of the 37 interviewed, 17 were female and are represented by even numbered code numbers. All the Form 5 pupils were taking School Certificate Science, and all the Form 6 pupils were studying Chemistry. A variety of schools in and around Hamilton were used. Student T1 scored 47 in Bursary Chemistry in 1980, and student T2 scored 47 in U.E. Chemistry in the same year.

be communicated to the interviewer. However, each view was gained after persistent questioning of the person being interviewed. Ravenette (1977) considers the question to be the basic tool of the researcher. Part of his professional skill lies in his ability to invent better and better questions. Better in this context means easy for the child to answer rather than difficult, neutral rather than leading, and penetrating rather than superficial. In each of the events chosen, a number of questions were asked until the interviewer felt he had clearly established the view of the interviewee. The crucial questions asked are included in the discussion that follows about each event.

After some trialling and changes in procedure[3] five events were used which produced useful information:

Event One	A Redoxon Vitamin C tablet was placed in water.
Event Two	Gas from a butane burner was lit.
Event Three	Sugar crystals were placed on a spoon and heated above the gas flame.
Event Four	Shiny, and rusty nails were observed.
Event Five	Holts Bond-o-Fill plastic filler and hardener were mixed.

The events chosen had two real advantages. On the one hand, they were reasonably familiar everyday examples involving chemical change[4], and on the other hand, pupils often talked about these events without recourse to scientific terminology. An event involving

---

3 As a result of the changes in procedure only 36 interviews about Event 2, and 29 interviews about Event 3 were used in the discussion that follows.

4 A scientist considers that in general, a chemical change occurs when chemical substances react to form different chemical substances. Some chemical changes occur without any visible change, e.g. when solutions of acids and bases react. Chemical change can be the reaction (usually called decomposition) of one substance only, e.g. the thermal decomposition of sucrose used in Event 3.

the making of pikelets was tried but rejected after six interviews since pupils were able to formulate a reasonable scientific viewpoint during the event itself. Such an event would have greater value for the teacher rather than the researcher who is interested in the pupil's present viewpoint.

Each interview proceeded in three phases. For each event the pupil was asked initially what he/she noticed. Secondly the pupil was asked for his/her view of what had happened. The replies given were explored further especially in the ways certain words were used. Questions such as "Can you put that another way?" or "What do you mean by ....?", or "Can you tell me more about that?" were used often in all events. The replies indicated aspects of the pupil's model of how and why things behaved as they did. This in turn gave some insight into the pupil's understanding of scientists' language and views of chemical change. The interviewer did not use such terms as chemical, chemical change or chemical reaction unless the person being interviewed did so.

Each interview was audiotaped and later transcribed. The views expressed for each event were categorised and are best considered by discussion about each event in turn.

EVENT ONE: A Redoxon Vitamin C tablet placed in water[5]

Pupils were asked to place a Redoxon Vitamin C tablet into a glass of water and observe carefully. Once the reaction was clearly apparent, discussion was initiated with the question "what do you notice?" An example of a typical response would be:

> "It's dissolving. It's making a noise. It's bubbling and spraying little bits out of the glass. It's smelling"
> (306)

---

5 The scientists' view is that the tablet contains chemicals that when put in water start dissolving. Some of these chemicals then come in contact with each other and react, releasing bubbles of carbon dioxide gas. This reaction and the agitation of the water, helps the Vitamin C dissolve more rapidly.

As the effervescence caused by the release of carbon dioxide gas subsided, further questions were used to explore more deeply the pupil's perceptions related to the event, e.g. "What is your view of what has happened to the tablet?" Meanings for words or phrases used in pupils' responses were also explored with questions such as "What do you mean by dissolving?"[6]

Attention in this event was focused on elucidating the interviewee's views of what the bubbles were made of, where the bubbles had come from and how the bubbles had come about. The question "What are the bubbles made of?" produced these replies:

Response	Responder	Total
Air	102, 201, 202, 203, 204, 205, 301[7] 302, 303, 309, 401, 402, 404, 405, 504, 604, T2	17
Carbon dioxide	208, 301, 406, 603, 605, 607	6
Gas	305, 403, 407, 502, 601	5
Oxygen	409, 501	2
Hydrogen	T1	1
Hydrogen & Oxygen	602	1
Bits of Vitamin C	307	1
I don't know	206, 304, 306, 503, 506	5

The views expressed by pupils regarding the origin of the bubbles were of three categories.

1. The bubbles resulted from a chemical reaction between the tablet and the water. For example:

> "When it hit the water it started to disintegrate. It gave off a created gas. (Can you put it another way?) Starts them off ... when the tablet hits the water there is a certain substance in there that creates the gas."
>
> (407)
>
> Also 201, 306, 401, 402, 403, 501, 601, 605, T1, T2.

---

6 Those interviewed used and interchanged words such as 'melting', 'dissolving' and 'evaporating' freely. Their meanings for such words however did not become the focus of attention.

7 Pupil 301 gave both responses, air and carbon dioxide.

The fact that the pupils had a view sympathetic to the idea of chemical change did not necessarily mean that they had a typical scientific view. For example:

> "The tablet is reacting with the water, splitting up the hydrogen and the oxygen. That's turning them into their gas forms and the gas comes out the top."
> (602)[8]

2. <u>The bubbles are caused by a physical change within the tablet</u> when it is placed in water. Various causes were given. For example:

> "... it must have been some sort of airlock in it and the air that's in it forces itself out and up to the top."
> (302)
> Also 202, 203, 301, 302, 309, 404, 405, 503, 604

> "When they made the tablet they put little air bubbles in ..."
> (205)
> Also 102, 204

> "They come from the tablet making air under water. (How does the tablet make air under water?) I don't know unless the room it took up went up in bubbles"
> (409)
> Also 406

> "There didn't seem to be any heat so I don't assume there was a chemical change in individual molecules; perhaps just the splitting off of molecules from the lattice as a whole"
> (607)

3. <u>It was not known how the bubbles were formed</u>.

Views were hesitantly expressed with a number of comments such as "I don't know" used. For example:

> "(What is your idea of how you have all these bubbles in the tablet?) ... I don't know ... (Any possibilities?) ... No."
> (504)
> Also 208, 303, 304, 506

Generally, an answer of "I don't know" prompted the interviewer to try a different approach, often with success. But the five pupils above had the view that the bubbles formed in some unknown way.

8 See also the Working Paper NO. 26 on Physical Change where the idea of water breaking up into oxygen and hydrogen when water

EVENT TWO: Gas from a gas burner was lit[9]

A butane gas burner was used. Most pupils correctly categorised the burner immediately it was produced suggesting some familiarity with the appliance. Before the gas was ignited, the tap was turned on and the interviewer asked the question "What do you hear?". All pupils indicated that a gas was coming out of the bottle. Once the gas had been lit, questions such as "What do you notice?", "What is your view of what is happening?", "What is up here?" (above the flame) were asked.

There were several problems. This event was the most difficult of the five (see page 2) with respect to gaining views of what the interviewee considered to be happening. Most interviewees considered that a change of some sort was occurring because of the presence of a flame. Their views of the nature of the change were most clearly indicated by the products they perceived as being formed. Details of how they saw the process involved was difficult to ascertain without extensive questioning, a practice which could have resulted in the interviewer losing the confidence and rapport of those interviewed[10].

One of the subtle problems was that frequently those interviewed were using two meanings for the word gas:

1. gas is fuel, usually a hydrocarbon;
2. gas is one of the states of matter.

Thus when a pupil (201) stated that "the gas above the flame is similar to the gas in the bottle", further questioning was required to determine which meaning of the word 'gas' was used.

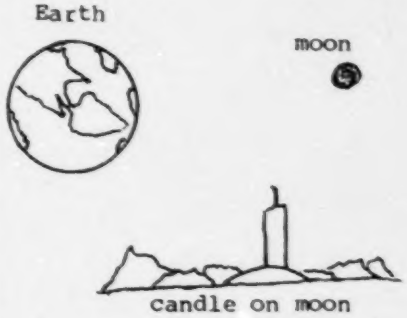
---

9 The scientists' view is that the gas (butane) reacts with oxygen of air producing carbon dioxide gas and water vapour. This is a chemical reaction in which energy is released in the form of heat and light.

10 Childrens' views of what a flame is made up of have been investigated in the Learning in Science Project Working Paper No. 18 on Particles.

The presence of a flame was a strong indicator to the 36 interviewed that the gas had changed in some way. But only nine pupils (303, 306, 401, 402, 403, 406, 502, 503, 601) suggested that oxygen or air was involved in the production of a flame. Eighteen of the others were asked: "Is anything else involved here?". Nine (102, 203, 205, 305, 307, 407, 504, 506, T1) answered "No" and nine (204, 208, 303, 404, 409, 505, 602, 604, T2) answered 'air' or 'oxygen'. Following this question, in some cases the views that had earlier been expressed were modified. Undoubtedly, some children have the view that while air is involved when something was burning, the view that something might still burn in the absence of air was also held. To establish the prevalence of this view, the following survey question was used:

There is no air on the moon. Would the candle burn faster or slower than on the earth or not at all?



a. Faster ☐

b. Slower ☐

c. Not at all ☐

Answer	Form 2 (N = 179[11]) %	Form 4 (N = 174) %	Form 6 (N = 166) %
a.	8	5	1
b.	5	4	0
<u>c.</u>[12]	87	91	99

There were four categories of views expressed by those interviewed regarding the products formed as a result of the gas burning.

---

11 One class surveyed was a composite F 1/2, with 20 Form 1 children generally of above average intelligence.

12 In the survey results given in this paper, the best answer from a scientific viewpoint is underlined.

A colleague has pointed out that the diagram as shown with the candle unlit could have been an indicator to younger children at least, that answer c. is the correct response.

1. When gas is lit or ignited, a chemical change occurs whereby different substances are formed. For example:

> "It's burning up but there are different gases released. When you burn up the gas, different gases are formed and released."
> (409)
> Also 204, 306, 401, 406, 503, 607, T2

Three of the sixth formers gave initial statements which superficially appeared compatible with the scientific view of chemical change. However views in conflict with the scientific explanation of the process were revealed after further questioning. For example, one pupil (605) thought that probably carbon dioxide and hydrogen were formed, but then said that oxygen and butane particles join together and "they just stay joined". Another pupil (604) had the view that the flame caused the butane gas molecules to break up; then they were released into the atmosphere. The other pupil's view was expressed in this way.

> "The gas is coming out where it mixes with the oxygen, then it burns. (Burns?) The oxygen is leaving. It's splitting up from the other gas molecules. (What's up here?) Heat and the oxygen ... that has been split up."
> (602)

2. Gas only is involved in making the flame, and this results in burnt gas, or 'something'. For example:

> "The gas is eating up, no, the flames are eating up the gas. The gas is what supplies the flame to keep it going. (What happens when it eats up the gas?) It eats it up and then it goes up in little pieces. (Is this the flame going up or something else?) Burnt gas or something, and heat."
> (307)
> Also 102, 203, 206, 302, 304, 403, 405, 407, 501, 505

Four of these pupils (102, 302, 405, 501) described the 'something' as soot or smoke.

3. Gas produces a flame which in turn produces heat. Many pupils mentioned heat as one of the products. Their meaning for the word 'heat' was explored. The six pupils in this category considered that heat was the product of the gas burning. For example:

"(What do you mean by burnt?) It passed through something which made it hot. The gas is vulnerable to heat. (Put that another way.) The heat mixes with the gas and makes a flame. (Does the gas change into a flame, or does it pass through, or ...?) It changes into a flame. (What happens further up?) It turns into heat or heat waves."
(205)
Also 303, 309, 502, 601, T1

Two of the pupils (502, 601) mentioned that air also was involved in the above process. The Teachers College student said there was a reaction occurring, but all the gas may not be 'combusting'. Then:

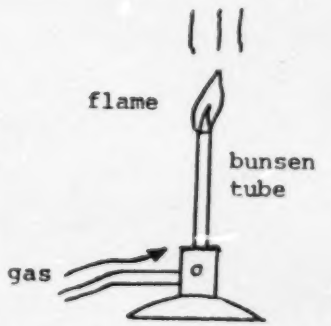
"(What happens to the gas that combusts?) It's utilised as heat. It's just gone, forming energy ... or is it? (Is anything else involved?) ... Just the pressure."

4. Gas above the bottle is similar to the gas in the bottle. Three pupils (201, 202, 206) held the view that the gas above the flame was not really different from that in the bottle. For example:

"(Are these fumes the same up here as the gas down here?) Yes, probably. (Has the gas changed?) Yes, a bit because up here its free to go and mix in with the air particles."
(202)

Responses to the following survey question clearly indicate the prevalence of this latter view in particular.

Above the flame it is hot. What is it that is hot?



a. air only ☐

b. air and the same gas as that in the bunsen tube ☐

c. air and a different gas from that in the tube ☐

d. air and different gases from that in the tube ☐

Answer	Form 2 (N = 179) %	Form 4 (N = 184) %	Form 6 (N = 166) %
a.	11	21	30
b.	47	48	40
c.	16	10	15
d.	26	21	15

In the sense that the gases formed when butane burns are carbon dioxide and water vapour, and that these substances can be found in air, answers (a), (c) and (d) have some scientific basis. But eight sixth formers who chose answer (a) were questioned individually about why they had made that response. Five mentioned that they had the idea that gas was used up when it burnt, so the flame heated the air above it. One boy said the response "had to be (a) because you couldn't see anything else formed". The other two explained that the products formed were part of the air anyway. A comparison of the survey results on p.7 and above suggests that a number of students consider air to be necessary for burning but not actively involved. Air being seen as a passive catalyst rather than something which undergoes chemical change in the burning process.

Clearly many pupils do not share the scientists' views regarding the products of combustion.

EVENT THREE: Sugar heated above the gas flame[13]

Some sugar crystals were placed on a spoon and heated over the gas burner. The sugar melted, then changed to a brown frothy liquid giving off clearly visible fumes. Questions such as "What do you notice?", "What is your view of what is happening to the sugar?" initiated discussion. Everyone interviewed used the terms 'melted' or 'dissolved' in describing the change of state of sugar from solid to liquid. Subsequent questions such as "What is your view of what the brown colour is?", "What are the fumes?" were asked.

---

13 The scientists' view is that sugar molecules break up when heated producing carbon (or carbon dioxide if the melted sugar ignites) and water vapour. If carbon is formed it can remain on the spoon or can be given off in smoke.

One particular problem was the existence of a mixture of melted sugar and carbon left on the spoon. The sugar was not heated sufficiently long for it to completely decompose to carbon. Thus the question "Has the sugar changed?" could have had two answers. No pupil indicated that there was a mixture of two substances present, but a few pupils did give a name to the brownness, e.g. flavour, syrup.

Basically there were just two views expressed by the pupils interviewed about this event:

1. <u>The melted sugar had broken up and new substances were formed</u>. Carbon, steam, and smoke were mentioned as likely products in some cases. Views compatible with the scientific position regarding this process of chemical change were spread through all age groups. For example:

> "(And what's coming off?) Smoke and steam. It could be smoke because it is burning and steam because it is very hot. (Is the smoke sugar?) It's probably parts coming out of the sugar and some of it going up in steam."
> (202)
> Also 201, 302, 307, 409, 503, 602, 605, 607, T1

Some older students' answers included some chemistry terminology although it was not always used in the appropriate manner. For example:

> "The sugar has melted. And the oxygen trapped in the crystals before, rise to the top to form bubbles. The sugar burns and forms a carbon compound ... the smoke coming off is carbon dioxide and comes from the mixture of oxygen and burning sugar." (503)

2. <u>The melted sugar changes to another form of sugar</u>.

The pupils made such comments as the sugar was 'bubbly, boiling, burning'. When asked for their meanings for those words, and their views of what they had observed happening when the sugar was heated, the following four types of views were evident: The sugar was

(a) in another form which included a colour change, or change of taste (203, 204, 208, 305, 307, 309, 407, 501, 506); or

(b) overcooked but still sugar (208, 305, 402, 501); or

(c) that colour because it was unable to 'take too much heat' (102, 205, 402, 404); or

(d) changed to sugar in the gaseous state (304, 306, 504).

The views of five pupils (208, 305, 309, 402, 501) fit in more than one of the above categories. The following are examples of the views expressed.

> "I reckon the sugar is not made for heat and it won't stand up to it so it has to give way and it melts away and burns. The particles sort of break up and go into a melty burnt substance. (Is that sugar there or is it something else?) It would be sugar but it's not too healthy. It's sugar in a different way." (309)

> "Well it's all melted up like butter, and it's shiny and it's very hot I suppose, sticky, mushy. (What could the brownness be?) Could be the flavour. It's like golden syrup. (What do you say the smoke is?) You're probably overdoing it." (305)

> "It's dissolved, gone from solid to liquid form. It's kind of fried, gone brown. It's got so hot that it can't take any more so it just got brown." (402)

> "It's probably evaporating. It could be the sugar evaporating." (504)

In summary, these results suggest that the majority of students viewed the change in the sugar more as a physical change than as a chemical change.

EVENT FOUR: Careful observing of shiny and rusty nails[14]

A shiny nail was shown to each pupil. A rusty nail was shown also. It was explained that the nail had been shiny too, but had been placed half submerged in water for a week. Everyone mentioned that it had rusted or was rusty as well. Three sixth formers said initially that the nail had oxidised. Questions such as "What do you mean by rusted?" (or rust, rusty, oxidised). "What is your view of what has happened?" were asked. The responses led to questions such as "What is your view of how the rust got there?", "What is the brownness?".

---

14 The scientists' view of how rust forms is that the nail (iron) and oxygen in the air (which may be dissolved in water) and water react together to form a new substance, the rust coloured hydrated oxide of iron.

The prevalent views were these:

1. Rust occurs as a result of a chemical change. Sometimes just water and the nail were seen to be the active agents in the rusting process. Sometimes oxygen (from the air, or dissolved in water, or as part of the water molecule) and the nail were seen to be the agents. Or all three substances, water, oxygen and iron were seen to be involved. The views were expressed in a variety of ways. For example:

> "Water and air have combined and reacted against this nail and its going to rot. (What do you mean by reacted against?) Well, it's reacted against the particles in this nail. It's started to rot ... it's overtaking the nail. (What's really going on there?) The particles are fighting ... it seems the water has got on here and it's sort of fighting and it's sort of overtaking it to form this red stuff. (What is rust?) Rust is the form of the chemical reaction after the nail has been taken apart by the rain."
> (403)

> "The water is taking a part of the iron which allows the iron to remain solid. The water forms another sort of compound which has the properties which the iron needs to remain in its normal charged state ... (Where's the oxide come from?) It's part of the iron itself. It's normal iron until it loses the charge and it becomes something new which doesn't have the properties of iron and which we know as rust."
> (607)
> Also 307, 503, 602, 604, 605, T1, T2

2. Rust is a coating on top of the nail. It can be a protective layer which stops the whole nail from decaying. For example:

> "The water eats away at the metal and the nail forms a protective coat to stop the whole thing decaying."
> (205)

> "Rust is a sort of a chemical. It breeds in the dampness. It's in the air all the time and when any steel is damp or anything, it spreads all over it and breaks it down ... it's sort of a fungi."
> (405)
> Also 302, 409, 504

3. Water plus some impurity in the nail causes the nail to rust. When the nail is put in water, the impurity comes out and rust results. For example:

"Water got into the steel and it has taken some stuff out of it and made the steel go like that and it weakens the steel. The water got into the paint and the ingredients of the steel." (305)

"The materials the nail is made of are probably compressed to make the nail, but when it is put in water some of the inside materials come to the surface of the nail and these materials go browny black like rust ... They have all sorts of things mixed in a nail, gases and materials mixed in with everything else." (204)

"The water reacts with the air and with an impurity within the nail." (603)
Also 206, 208, 406

4. Rust appears once the shiny outer surface of the nail is removed. The view of this group is that rust is actually present under the shiny surface and it becomes apparent once the nail is soaked in water. It seems that the children with this view are considering the peeling of, say, chrome bumpers, revealing rust underneath.

"It's actually under the nail. It's been painted. It had a solid coat over it. I'm not sure what the silver coat is for but the silver coat has worn out and the rust has come out underneath. When you put something like this in water it expands and just floats apart and this has got very soft and peeled off." (202)
Also 102, 203, 401, 402, 404, 407, 502

5. Rust is the result of water eating away at the nail. The view of this group was that the water 'eats' away at the nail, especially the surface layer. For example:

"Water is eating into the nail and the nail would eventually disappear over a period of time. (Would you be left with nothing?) Well, not much anyway." (601)
Also 301, 306, 309, 501

6. Rust just happens when a nail is in water. Rust is merely a natural result of putting a nail in water. It was hard to find any clear cut view of the four (201, 303, 304, 506) in this category.

"I'm not sure ... it just somehow forms." (201)

Many of those interviewed confused the rusting process itself with the effects of rusting as seen in everday life. With this in mind two survey questions were used to determine children's understanding of the rusting process.

A. Some shiny nails go rusty when put in or near water. Before such nails go rusty, where is the rust?

a. nowhere, as it does not exist ☐

b. in the air ☐

c. in the water ☐

d. in the nail itself ☐

B. When a nail goes rusty, does the rusty nail:

a. increase in weight? ☐

b. decrease in weight? ☐

c. stay the same weight? ☐

Answer (a) would be considered the scientists' view in each case.

A. Answer	Form 2 (N = 179) %	Form 4 (N = 174) %	Form 6 (N = 166) %
a.	26	31	84
b.	11	16	1
c.	26	20	6
d.	37	33	9

B. Answer	Form 2 (N = 179) %	Form 4 (N = 174) %	Form 6 (N = 166) %
a.	15	18	39
b.	37	42	33
c.	48	40	28

It is apparent from the interviews and from the survey data that many pupils do not hold the scientists' view of what rust is and how it occurs. In fact some pupils argued strongly to retain their own views when questioned after the survey was completed. With such diverse views

expressed in all 21 classes surveyed, there appears to be considerable opportunity for discussion and suitable experimental work, in order to resolve the varying viewpoints.

EVENT FIVE: Holts Bond-o-Fill plastic filler[15]

Holts Bond-o-Fill was used for this event. Each pupil was invited to stir together the light brown plastic filler and the vivid blue hardener. After about three minutes the mixture rapidly solidified. As well a gas with a distinct odour was given off during the period of stirring. The two crucial questions asked were "What is your view of what happened?" and "What is your view of how the mixture went hard?". When asked to feel the product, most noticed that it was warm. Half the pupils considered that some form of reaction had occurred. However, some pupils suggested that the effect was the result of the friction between the wooden stirrer and block, or between the particles themselves, or that the heat was generated as a result of a chemical reaction.

The following views about the event itself were expressed.

1. The two substances mixed and formed one or more new substances, including a gas. The 13 pupils who held this view were clear that at least one new substance was formed, and this was different from the product resulting from the mere mixing of the two reactants.

> "This chemical here has been specially made for this chemical so when you mix them together they sort of combine to form this hard stuff ... they make a new substance in solid form." (205)
>
> "There are two - I'm not sure - chemicals, and they meet, they combine to make material and it sort of bonds, it wants to match and it's when it combines, it becomes one." (401)
> Also 208, 301, 309, 403, 407, 502, 503, 603, 605, 607, T1)

---

15 The scientists' view is that the two substances mix together and form a new substance. This reaction occurs quickly once the bonds of an inhibitor (substance included to slow the reaction down) have been broken and the resulting gas evolved.

2. The two substances mixed and this mixture hardened. There were several causes for this observed result.

(a) One of the substances (the hardener) went hard forming a structure or matrix which held the other substance rigid. For example:

"When you mixed the two glues together, the hardener goes hard and holds the other stuff in ... the other stuff makes a bigger amount of the glue so you can fill gaps."
(307)
Also 201, 206, 405, 409

(b) The liquid or solvent in the mixture evaporated leaving a hard solid. For example:

"The liquid is evaporating and it's going harder. It hasn't got anything to keep it liquid and all the molecules are starting to slow down because there isn't any medium to move in."
(602)
Also 204, 406, 504, T2

(c) The two substances mixed and set as jelly, fudge, toffee would solidify. For example:

"The bits here mixed and come together. (What else?) They've hardened. I think it's the temperature. Like when you are boiling toffee and when you put it into cold water it hardens."
(302)
Also 102, 303, 304, 305, 501, 604

3. It happened but how was a mystery.

"It's ... just ... it's I don't know really. It's just two chemicals mixed together which makes it form a hard plastic filler."
(202)
Also 306, 506

There were three (203, 402, 404) views expressed which did not fit any of the above groups. For example:

"There's something in the hardener that disagrees with the plastic filler and the mixture just clings together or sticks together."
(402)

Chemical Change and Chemistry

Where such terms as chemical change, chemical reaction or chemistry had not arisen during an interview these terms were introduced in a casual manner at the end of the interview. For example:

> "(You might have heard about Biology?) Yes we're doing that ... (Have you heard of Chemistry?) Chemistry is like nursing. You've got medicines and injections. (So would this be Chemistry?) No. (What about some other things in science? Have you used a word reaction?) Oh yes, like when someone punches you or slaps you away, you shut your eyes. (What about chemical change?) Well that's like the sugar; it's still sugar. It goes into watery stuff and changes." (102)

It is clear that pupils have a variety of meanings for Chemistry and chemical change. Five pupils were asked for their meaning of the word 'Chemistry'. Their responses were:

> "Never heard of it." (306)

> "Mixing up things and making potions that go bubbly. (Is this anything to do with Chemistry?) Yes, the mixing of the glue and the tablet." (307)

> "Mainly mixing things together to make other things." (204, 401)

> "Chemistry is finding out above our atmosphere." (405)

One pupil (303) was asked "Do you think this is related to Chemistry?" His reply "No, I think you are just asking me these questions like you have hearing tests and eye tests".

Seven pupils were asked about their meaning of chemical change, and instances of physical and chemical change explored. Some replies were:

"Two different chemicals coming together and they react with one another, and if one doesn't like the other, they separate and become different forms. (Is water boiling and turning to steam a chemical reaction[16]?) Yes, the heat forms with the water to form steam. (Is sugar dissolving a chemical reaction?) No ... Yes, for the taste of the sugar rises in the glass?" (205)

"When substances react with each other to form different substances. (Does sugar dissolving in water involve a chemical change?) Yes." (604)

"Like when you mix salt and flour together, it's two different chemicals for cooking, they all mix together so they become one chemical." (202)

Two pupils (201, 504) said both sugar dissolving and water boiling involved chemical change. Thus it seems that pupils have a far wider meaning for the term 'chemical change' than do scientists. Children's views can show that any change, whether it be shape, colour, state can be considered a chemical change. Two of the survey questions which specifically indicated children's understanding of the terms 'physical change' and 'chemical change' are shown with the survey results.

A. A girl sips some orange cordial. It tastes too strong. She adds water to the cordial. What sort of change is she making?

a. physical change ☐

b. chemical change ☐

c. neither ☐

B. When sugar dissolves in water does a physical change or a chemical change occur, or both, or neither?

a. physical change ☐

b. chemical change ☐

c. both ☐

d. neither ☐

16 The word reaction was used if the pupil had used it previously.

A.	Answer	Form 2 (N = 179) %	Form 4 (N = 174) %	Form 6 (N = 166) %
	a.	16	21	36
	b.	73	68	50
	c.	11	11	14

B.	Answer	Form 2 (N = 179) %	Form 4 (N = 174) %	Form 6 (N = 166) %
	a.	18	28	23
	b.	37	22	22
	c.	40	48	55
	d.	5	2	0

From these responses and other responses to the three similar questions (these involved toast burning, ice melting and water boiling, see Appendix A) used in the survey, it is clear that many pupils can not adequately differentiate between instances of physical and chemical change, and were unclear about what criteria to use. A subsequent question in the survey asked students to explicitly state what they meant by physical and chemical change. The answers from more than 500 pupils indicated confusion between the two terms. Even some sixth form students were confused. For example, three of the sixth formers gave these meanings for physical change:

"When something changes its form from what it was before."

"One where the reaction doesn't break up the compounds."

"Change of physical properties (colour, odour etc.). Can be easily reversed back to its original form."

The same pupils gave these meanings for chemical change:

"Is when the molecular form is changed by doing something, e.g. adding or removing water."

"One where the compounds are broken to form new compounds."

"Change to a different form or state. Is not easily reversed."

The three pupils who gave these meanings all considered sugar dissolving to involve chemical change only.

A pupil who answered (a) for both questions 8, and 9, on the survey had a view much closer to the scientific view for physical change (e.g. "a change of state or a change visible to the naked eye") and chemical change (e.g. "a new compound or substance is formed by the change"). Such views could be found in pupils of varying ages, but with greater frequency in older pupils.

Summary

As in all the other studies undertaken in the in-depth phase of the Learning in Science Project, this study shows that children do have ideas about how and why particular events do occur. In this case children do have ideas about events involving chemical reactions. However their ideas about what is happening and why, and indeed their meaning for the word chemical reaction is frequently quite different from the scientific viewpoint. From this perspective teaching scientific knowledge needs to be seen as a reshaping, or modifying, of children's views rather than transmitting new knowledge to blank minds.

If you as the reader have any comments on the views discussed in this paper, and in particular, on their implications for the teaching of science, we would be most interested to discuss your views with you.

Acknowledgements

I record my thanks to the many young people who contributed to this study, and to their teachers for their assistance and interest.

I thank in particular Roger Osborne and Ross Tasker for their significant contributions at each stage of the development of this paper.

References

Department of Education: Science Forms 1-4 Draft Syllabus and Guide
Wellington, N.Z. (1978)

Osborne, R.J. "Some aspects of the Students' View of the World"
Research in Science Education Vol. 10, 1980, p11-18.

Ravenette, A.T. Psychological Investigation of children and Young People. In Bannister, D. (Ed)
New Perspectives in Personal Construct Theory
London: Academic Press, 1977

5801A

APPENDIX A

10. When toast burns does and physical change or a chemical change occur or both, or neither?

a. physical change ☐

b. chemical change ☐

c. both ☐

d. neither ☐

11. Ice melting in a glass involves:

a. physical chang Yes ☐ No ☐

b. chemical change Yes ☐ No ☐

12. Water boiling in a kettle and changing to steam involves:

a. physical change Yes ☐ No ☐

b. chemical change Yes ☐ No ☐

10. Answer	Form 2 (N = 179) %	Form 4 (N = 174) %	Form 6 (N = 166) %
a.	53	43	26
b.	9	19	19
c.	29	31	52
d.	9	7	3

The percentage of those answering "Yes" are given for each part of Questions 11 and 12.

Answer	Form 2 (N = 179) %	Form 4 (N = 174) %	Form 6 (N = 166) %
11. a.	76	92	99
b.	38	32	14
12. a.	63	78	96
b.	53	51	23